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Does 2,4-dichlorophenoxyacetic acid induce flowering in sweet potato?

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Most sweet potato cultivars grown in Zimbabwe are poor in agronomic and quality traits and require improvement through breeding. However, most cultivars rarely flower yet the flowers are crucial in genetic improvements. The aim of this study was to determine the effects of different levels of 2, 4-dichlorophenoxyacetic acid (2,4-D) on sweet potato flower induction. A 3*4 factorial experiment in a randomized complete block design with three replications was used. The first factor was landrace with three different landraces and the second factor was 2,4-D with four different concentrations (0, 100, 300 and 500 ppm). The 2,4-D was applied 50 days after planting. Sweet potato landraces that were sprayed with 2,4-D showed morphological and physiological disorders that included temporal drooping, petiole epinasty, stem splitting, shoot dieback and root swelling. Extensive morphological and physiological disorders were observed on landraces that were sprayed with the high levels of 2,4-D (300 and 500 ppm). However, within 30 days, all the landraces that were sprayed with 2,4-D managed to initiate buds and set flowers while the plants that were not sprayed did not flower at all. The Friedman's tests showed no significant differences in bud and flower number among the treatment combinations used. Therefore the lowest concentration of 2,4-D (100 ppm) used in this study is probably close to the optimum concentration for flower induction in sweet potato. Although this concentration is not the actual optimum, at the moment this concentration can be used to induce flowering in sweet potato and thus allow sweet potato breeding initiatives to be launched.

Key words: Sweet potato, 2, 4-dichlorophenoxyacetic acid, flowering, seed set.

INTRODUCTION

In Zimbabwe, sweet potato consumption exceeds 3 to 5 kg per capita per annum (Mutandwa, 2008). Orange-fleshed landraces provide β-carotene, a precursor of vitamin A that is frequently lacking among children (Kapinga et al., 2010). Furthermore, sweet potato is a low input crop that performs well in marginal areas common in the drier parts of Zimbabwe (Mutandwa, 2008; Kapinga et al., 2007). Given the paramount importance of sweet potato, there is need to initiate breeding programs in the country aimed at improving sweet potato to accommodate various uses. For example, most landraces grown by farmers rarely exceed 0.5 t/ha (Mutandwa, 2008). Furthermore, most landraces are susceptible to the sweet potato virus disease (Gasura and Mukasa, 2010) and

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also lack other desirable traits that include high dry matter content and elevated levels of β-carotene and tolerance to drought (Kapinga and Carey, 2003; Mwanga et al., 2007; Gasura et al., 2008; Mutandwa, 2008; Grüneberg et al., 2009).

Sweet potato breeding in Zimbabwe is made complex by the absence of flowers or existence of scanty flowers. Under normal field conditions, some landraces do not flower at all (Huamán, 1999; Gasura et al., 2008). The production of flowers and sexual seed in sweet potato is controlled by genetic and environmental factors. Therefore, several techniques have been developed to promote sweet potato flowering and seed set. These include a short photoperiod, moderate temperature, limited water supply, trellising vines, overwintering, vine girdling, nutrition manipulation and use of growth regulators. Grafting of non-flowering sweet potato onto flowering stocks of other landraces or wild relatives of the *Ipomoea* species can induce flowering (Leopold, 1958). Although these methods of flower induction have been reported elsewhere they are yet to be tried in Zimbabwe.

The choice of a method to use in flower induction depends on its efficacy and feasibility. The advantage of a growth regulator such as 2,4- dichlorophenoxy acetic acid (2,4-D) is that it can be easily applied to a large number of landraces. At low concentration, 2,4-D stimulates flowering (Grossmann, 2007). It readily penetrate leaves, roots and stems and is rapidly transported via the symplastic and apoplastic pathways (Chinalia et al., 2007) and stimulate excessive biosynthesis of ethylene and abscisic acid (Chinalia et al., 2007; Grossmann, 2010).

Increase in endogenous ethylene and abscisic acid results in vine drooping, leaf epinasty, tissue swelling, stem cracking and leaf senescence. These physiological disorders results in the cascading of various signals that further switch on a series of genes involved in floral organs development and flowering (Tan and Swain, 2006; Ausín et al., 2005; Lohmann and Weigel, 2002). The main environmental factors influencing flowering in sweet potato are day length and temperature. Sweet potato is a short day plant and flowering is induced by using photoperiods of 8-11.5 h of intense light (Huamán, 1999). Flowering and fruit set are highest with temperatures of 20-25°C and a relative humidity of over 75% (Huamán, 1999).

Evaluation of the efficacy of 2,4-D in floral induction will assist in the initiation of sweet potato breeding program through artificial hybridization. Furthermore, this will enable genetic diversity assessment based on floral traits. Therefore floral induction will facilitate the development of landraces with superior agronomic traits thus enabling sweet potato to become an important food security crop in the country. The objectives of this study were to assess the effect of 2,4-D on sweet potato flower induction, and to determine the optimum level of 2,4-D that can effectively induce flowering in sweet potato.

MATERIALS AND METHODS

Trial site description

The experiment was carried out in the fields at the Department of Crop Science, University of Zimbabwe (17.78° S, 31.05°E). The site is in Natural Region IIa with an altitude of 1 400 m above sea level. The mean annual rainfall ranges from 800-1000 mm. The mean annual temperature ranges from 15-27°C. The soil type is predominantly red clay containing 1 and 30% organic matter and clay, respectively.

Sweet potato establishment and management

Three sweet potato landraces previously collected by the Department of Crop Science, University of Zimbabwe were planted using a 3*4 factorial experiment in a randomized complete block design with three replications. Each plot consisted of two mounds of soil with an inter-row spacing of 1.5 m and an in-row spacing of 1.0 m. Two sweet potato plants were planted at each mound. Compound D fertilizer ($7N:14P_2O_5:7K_2O$) was applied as a basal dressing at a rate of 300 kg / ha. Weeding was done by hand hoeing. Top dressing using ammonium nitrate at a rate of 60 kg / ha was applied six weeks after planting. Vines were put onto 2.0 m bamboo tripod stakes. Four levels (0, 100, 300 and 500 ppm) of 2,4-D ($C_6H_6Cl_2O_3$, molecular weight 221.04) were applied with a hand sprayer 50 days after planting. A plastic curtain was used to prevent drift of 2,4-D. The experimental site was rain-fed and irrigation water was applied to supplement the rains when necessary.

Data collection and analyses

The changes in the sweet potato plant morphology and physiology that include vine drooping, petiole epinasty, stem splitting, shoot dieback and root swelling were noted. The number of days from spraying to bud and flower formation were recorded. The numbers of buds and flowers produced per plot were counted on a daily basis and the cumulative bud and flower counts were obtained over 30 days. The bud and flower numbers were subjected to Friedman's test using Genstat software version 14 (Genstat, 2010).

RESULTS AND DISCUSSION

After spraying 2,4-D to sweet potato, various morphological and physiological changes occurred on health plants (Figure 1A) that included temporal stem drooping (Figure 1B) that recovered within 24 h, petiole epinasty (Figure 1C), root swelling (Figure 2A) and stem splitting and shoot dieback (Figure 2B). These morphological and physiological disorders were extensive in plots that received high doses of 2,4-D (300 and 500 ppm) compared to the plots that received a lower dose (100 ppm). No morphological and physiological changes were observed on non-sprayed (0 ppm) plants.

Sweet potato plants that were not sprayed with 2,4-D (0 ppm) neither initiated buds nor flowered. Buds and normal flowers were observed on all landraces that were sprayed with 100, 300 and 500 ppm of 2,4-D. However, only a few plots had plants with flowers and could not allow analyses of variance for the days to bud and flower

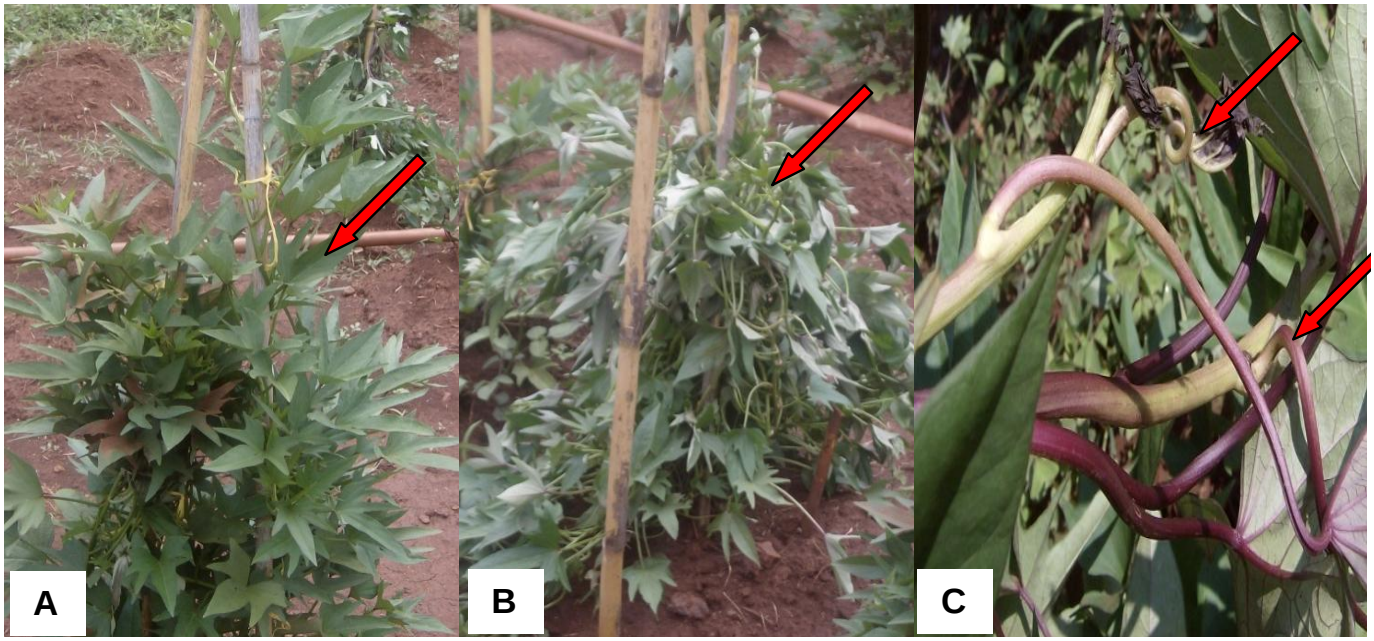

Figure 1. Healthy sweet potato (A), drooping vines following spraying with 2,4-D (B) and petiole epinasty (C).

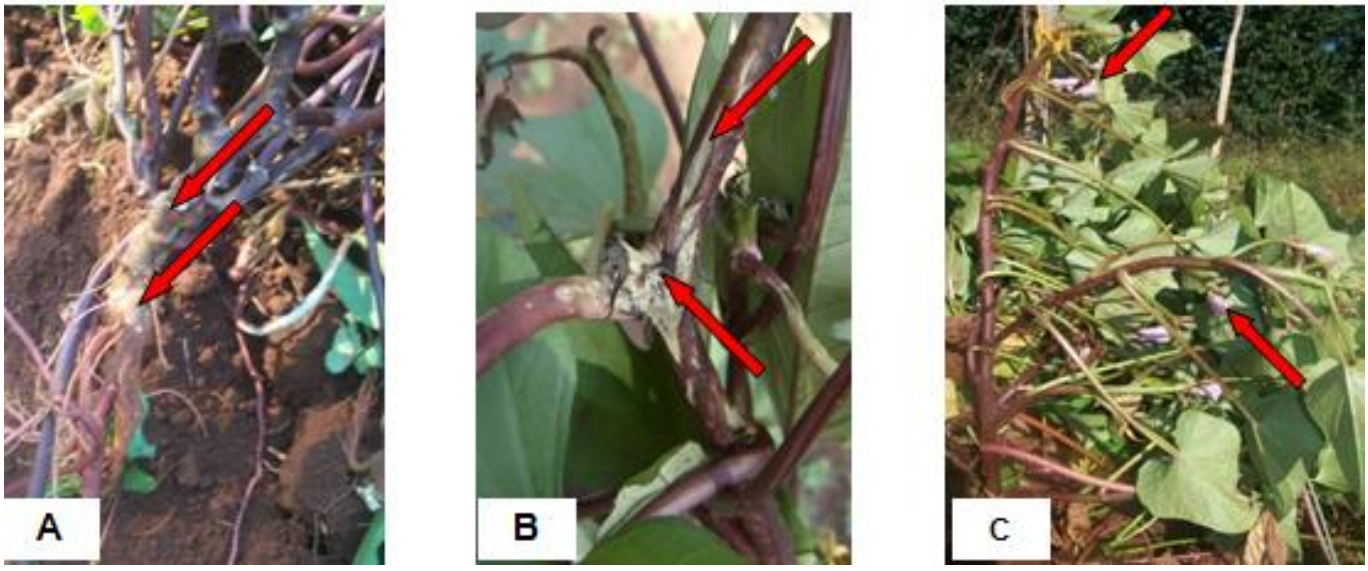

Figure 2. Sweet potato showing root swelling (A), stem splitting and shoot die back (B) and flowers (C).

initiation to be done. Nonetheless, sweet potato landrace 3 was the first to come into flower followed by landrace 1 (eight days later) and finally landrace 2 (14 days later). A total of six out of 12 treatment combinations (landrace * 2,4-D level) showed the presence of buds and flowers. These six treatment combinations included all the landraces and the three levels where 2,4-D was applied (100, 300 and 500 ppm). The six treatment combinations allowed the number of buds and flowers to be subjected to Friedman's non-parametric test. The Friedman's test of the six treatment combinations showed no significance difference in bud numbers (Figure 3) and flower numbers (Figure 4). However, landrace 3 with either 100 or 300 ppm had a relatively high number of buds and flowers although it was not significantly different from the rest.

The results demonstrate that 2,4-D is effective in inducing flowering in all three sweet potato landraces studied. This proved that flower induction is controlled by both

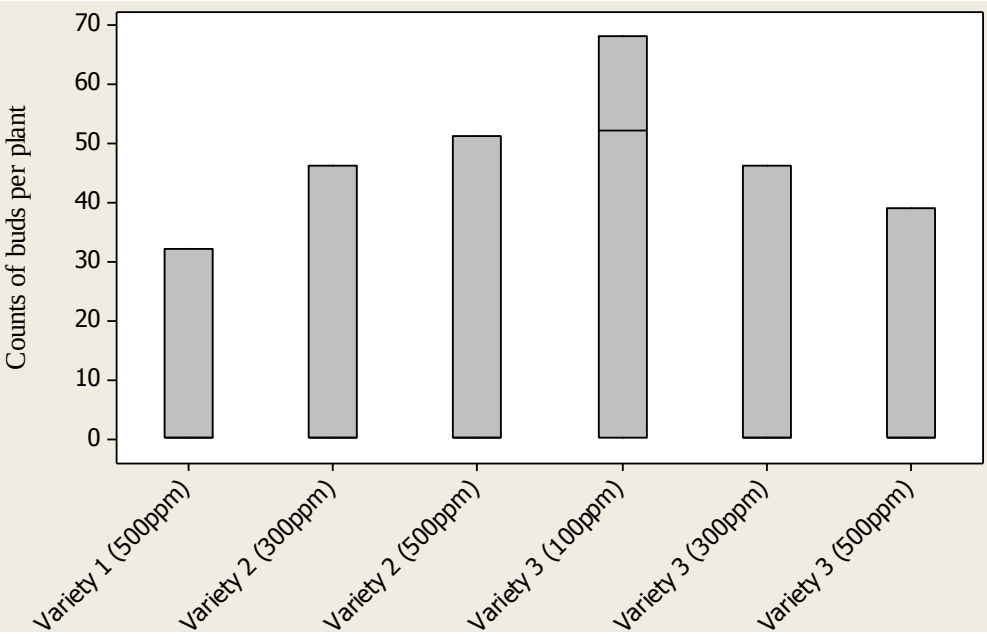

Figure 3. Box plot showing effects of variety and 2,4-D combinations on bud number of three sweet potato varieties (P=0.708).

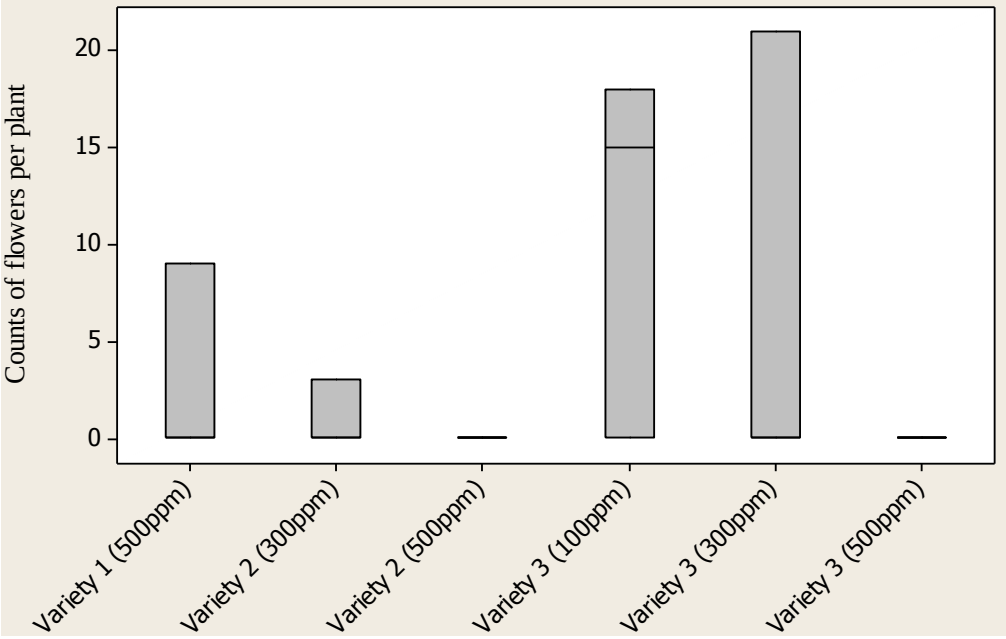

Figure 4. Box plot showing effects variety and 2,4-D combinations on flower number of three sweet potato varieties (P= 0.223).

external and internal factors (Ausín et al., 2005). The occurrence of non-significant differences among the treatments with various combinations of 2,4-D could reflect that the concentrations used went beyond the optimum, thus resulting in the absence of a clear pattern. Level two (100 ppm) is close to the optimum level of flower induction as it permits a lower 2,4-D concentration to be used while producing the number of buds and flowers that is comparable to the higher concentrations used. Thus, use of 100 ppm is not only cheap but also reduces

the extent of foliar damage as was observed at higher concentrations of 2,4-D (300 and 500 ppm). Further studies must attempt to investigate the effects of 2,4-D concentrations that are lower than 100 ppm. The morphological and physiological disorders observed after the application of 2,4-D were typical of the ethylene and abscisic acid signaling pathways as previously reported by Grossmann (2010). Ethylene is involved in plant responses to stress and the regulation of senescence. Ethylene results in re-orientation of microtubules from a transverse to a more longitudinal orientation which leads to lateral cell expansion. This expansion was observed as cracking of stems, root swelling and petiole epinasty (Grossmann, 2007). Stress induced by these abnormal hormone levels acts as a stimulant of transcriptional factors to induce flowering (Wada and Takeno, 2010). Therefore morphological and physiological disorders observed following 2,4-D sprays should be noted as a key step towards the floral induction rather than as an undesirable symptom.

The 2,4-D managed to induce flowering especially when applied at low concentration (100 ppm). At low concentration 2,4-D had a stimulatory effect on plant growth and development. Effectiveness of 2,4-D as method of flower induction in sweet potato was first reported by Howell and Wittwer (1954) and later in combination with grafting (Lardizabal and Thompson, 1990). Howell and Wittwer (1954) recorded relatively high flowering in all 2,4-D treated sweet potato plants as observed in our study. However, in their studies, Howell and Wittwer (1954) reported 500 ppm as the optimum concentration that effectively induced flower in sweet potato. However, our findings showed 100 ppm to be close to the optimum concentration. The difference in the optimum concentration observed by Howell and Wittwer (1954) and in our study could be attributed to the plot sizes and sweet potato cultivars used.

Our study used two mounds as the plot with two plants per each mound and thus the dosage applied for each plot was adequate to those few plants. Use of two plants per mound is typical of the require-ments of the nursery design to be used in breeding. Furthermore, the use of the plastic curtains also minimized drift and ensured that each application rate used was adequate for each plot. Differences in concen-trations could also depend on the foliage size of each landrace, with the landraces with huge foliage biomass requiring more dosage than those with small foliage.

The development of flower induction methods that is based on 2,4-D is a key step towards establishing a sweet potato crop improvement program. An effective method of flower induction developed in this study through use of 2,4-D sprays will enable sweet potato hybridization to take place. Controlled pollination ensures specific gene combinations to be made. Controlled sweet potato hybridization will allow the improvement of root yield, dry matter content and vitamin A content as well as tolerance to pests, diseases and drought. This will eventually lead to increased sweet potato production per unit area in the country.

Conclusions

The results show that 2,4-D can effectively induce sweet potato flowering when foliar applied at 100 ppm at 50 days after planting. Further studies must determine the actual optimum concentration of 2,4-D that can induce flowering and investigate the effects of different landraces, temperature, day length, ratoons and split application of 2,4-D on sweet potato flowering.

ACKNOWLEDGEMENTS

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REFERENCES

Ausín I, Alonso-Blanco C, Martínez Zapater JM (2005). Environmental regulation of flowering. Int. J. Dev. Biol. 49:689-705.

Chinalia FA, Regali-Seleghin MH, Correa E (2007). 2,4-D Toxicity: cause, effect and control. Terr. Aquat. Environ. Toxicol. 1:24-33.

Gasura E, Mashingaidze AB, Mukasa SB (2008). Genetic variability for tuber yield, quality and virus disease complex traits in Uganda sweet potato germplasm. Afr. Crop Sci. J. 16(2):147-160.

Gasura E, Mukasa SB (2010). Prevalence and implications of sweet potato recovery from sweet potato virus disease in Uganda. Afr. Crop Sci. J. 18(4):195-205.

Genstat (2010). Genstat Release 13.3 (PC/ Windows Vistal). VSN International Ltd.

Grossmann K (2007). Auxin Herbicide Action: Lifting the veil step by step. Plant Signal. Behav. 2:421-425.

Grossmann K (2010). Auxin herbicides: Current status of mechanism and mode of action. Pest Manag. Sci. 66:113-120.

Grüneberg WJ, Mwanga R, Andrade M, Espinoza J (2009). Selection methods part 5: Breeding clonally propagated crops, in: Plant Breeding and Farmer Participation. International Potato Center (CIP), Lima, Peru. pp. 275-322.

Howell MJ, Wittwer SH (1954). Chemical induction of flowering in the sweet potato. Sci. Ser. 120:717-720.

Huamán Z (1999). Sweet potato Germplasm Management Training Manual. International Potato Center (CIP), Lima, Peru.

Kapinga R, Tumwegamire S, Ndunguru J, Andrade MI, Agili S, Mwanga RO, Laurie S, Dapaah H (2010). Orange-Fleshed Sweet potato for Africa catalogue of orange-fleshed sweet potato landraces for sub-saharan Africa. International Potato Center (CIP), Lima, Peru.

Kapinga R, Zhang D, Lemaga B, Andrade M, Mwanga RO, Laurie S, Ndoho P (2007). Sweet potato crop improvement in sub-Saharan Africa and future challenges, in: Sweet potato Crop Improvement in sub-Saharan Africa and Future Challenges. Presented at the Proceedings of the 13 th ISTRC Symposium, Arusha, Tanzania. pp. 82-84.

Kapinga RE, Carey EE (2003). Present status of sweet potato breeding for eastern and southern Africa, in: Sweet potato Post-harvest Assessment: Experiences from Tanzania. Natural Resources Institute, Chatham, UK. pp. 3-8.

Leopold AC (1958). Auxin uses in the control of flowering and fruiting. Annu. Rev. Plant Physiol. 3:281-310.

Lohmann JU, Weigel D (2002). Building beauty: The genetic control of floral patterning. Dev. Cell 2:135-142.

Mutandwa E (2008). Performance of Tissue-Cultured Sweet potatoes Among Smallholder in Zimbabwe. The Horticultural Research Institute Report.
Mwanga ROM, Niringiye C, Lemaga B, Kapinga R, Yencho GC, Odongo B (2007). Breeding efforts to develop high-yielding, multiple pest-resistant sweet potato germplasm in Uganda, in: Proceedings of the 13 Th ISTRC Symposium. International Potato Center (CIP), Arusha,Tanzania. p.12.
Tan FC, Swain SM (2006). Genetics of flower initiation and development in annual and perennial plants. Physiol. Plant. 128:8-17.
Wada K, Takeno K (2010). Stress-induced flowering. Plant Signal. Behav. 5:944-947.